Government of Canada / Gouvernement du Canada
Fisheries and Oceans / Pêches et Oceans
Environment Canada / Environnement Canada





# ENVIRONMENTAL RISKS FROM OFFSHORE EXPLORATION

## AN OVERVIEW PREPARED FOR THE "OCEAN RANGER" COMMISSION

By

Fisheries and Oceans, Newfoundland Region
Environment Canada, Atlantic Region

Canada

# ENVIRONMENTAL RISKS FROM OFFSHORE EXPLORATION

AN OVERVIEW PREPARED FOR THE "OCEAN RANGER" COMMISSION

By

ENVIRONMENT CANADA

And

FISHERIES AND OCEANS



January, 1984

The editors, R.J. Wiseman and R.P. Côté wish to express their thanks and appreciation to the contributors of major sections of this report. These are:

| | |
|---|---|
| Dr. J.F. Payne | Fisheries Research Branch, Department of Fisheries and Oceans |
| Mr. L.H. Bain | Fisheries Research Branch, Department of Fisheries and Oceans |
| Dr. A. Gaston | Canadian Wildlife Service, Environment Canada |
| Mr. H.A. Hall | Environmental Protection Service, Environment Canada |
| Mr. R. Percy | Environmental Protection Service, Environment Canada |
| Mr. S. Dewis | Environmental Protection Service, Environment Canada |

## PREFACE

As a general comment, the overall risk is considered low now but this situation will change as exploration activities increase. In addition, while the risk of spillage of large quantities is greater during production, the incidence of blowouts is greater during exploration. In terms of relative risks to the environment, catastrophic events associated with oil and gas exploration must be placed in context with other discharges of oil and chemicals which tend to be chronic and widespread. It must however, be noted that quantifying the risks is a difficult task because of our incomplete knowledge of marine ecosystems.

The risks to biota from oil are best evaluated by considering the marine food chain. Effects on plankton will likely be undetectable and negligible and in the worst case, the impacts should be restricted to discrete areas of high level contamination. Damage to seaweeds would also be localized though major perturbations in salt marshes, areas of low energy but high productivity, would be significant. Benthic invertebrates are usually protected however large mortalities could be expected in shallow intertidal communities.

With pelagic fish, acute toxic effects are possible in the immediate area of an offshore oil spill. This is especially true in the case of eggs and larvae, but the potential for measurable impact on fish stocks is generally viewed as being slight or negligible. The risk to seal populations is considered low as the latter are widely distributed and contamination of any species would likely be restricted to a small portion of the total population. The same situation applies to whales.

The biota at greatest risk are seabirds, particularly the 2 million Thick-billed murres which leave Hudson Strait for the Grand Banks in late summer and are flightless for most of the journey. As a general comment, the coasts of eastern Canada support the majority of the western Atlantic populations of all marine birds except Dovekie and Roseate Tern. In winter, the Newfoundland banks are the single most important feeding areas for marine birds. A large spill in the wrong place at the wrong time could have serious consequences for a substantial portion of eastern Canada's seabirds. Therefore the risks during the period January to March are considered high.

Other hazards associated with oil and gas exploration including drilling fluids, dispersants, seismic survey, noise and debris would be expected to have very localized impacts. The risks are of course related to the magnitude of the exploration activities.

Exploration activities can also have some economic impacts linked to environmental hazards. The most significant risk of this nature may relate to the tainting of fish flesh and perceptions of the public linked to a major spill which in turn may affect the marketability of the product. Other aspects include contamination and fouling of fishing gear, fishing exclusion zones, and loss of seabirds as a food source, a small but important part of the local economy of some communities. Many of these impacts can be mitigated by financial compensation.

A final component of the determination of risk is related to the ability of existing countermeasures technology. Long transportation routes, a cold climate, a variety of sensitive environments combine to make east coast spill contingency planning, prevention and response a difficult task. Delays in instituting cleanup actions will therefore increase the spread of the oil in the environment and make the cleanup more difficult and costly. Our ability to predict spill trajectories is currently limited by the unreliability of data for current and winds. While considerable dispersion and degradation of oil does take place in the open ocean, for most winter conditions on the east coast, the available countermeasures equipment is generally ineffective. Thus where the risks are high, little exists to reduce them.

The acceptability of the risks is related to the degree of intervention in the management and operation of exploration activities. In turn, the degree of intervention is linked to the amount of time and money that industry and government will expend to reduce the risks. The interventions range from equipment standards and training requirements, through increased and improved meteorological forecasting and ice surveillance to limitations on winter drilling especially during the critical period when storms and wintering seabird populations combine to raise the risks. It must also be noted that the environment is only one of the factors considered in decisions on the acceptability of the risk.

As a concluding comment, it is worth emphasizing that once oil is released to the sea, especially with the wind and sea-state conditions prevailing on the East Coast, ninety percent or more will not be recovered. Dispersion and degradation will occur but some damage will be done. At the wrong time in the wrong place that damage could be significant. Due to the capabilities of the existing countermeasures technology, the phrase "an ounce of prevention in worth a pound of cure" takes on a real meaning.

# TABLE OF CONTENTS

PAGE

# 1. INTRODUCTION

The Director of Studies for the Royal Commission on the Ocean Ranger Marine Disaster jointly requested Environment Canada and the Department of Fisheries and Oceans to cooperate and provide comments on potential environmental impacts resulting from offshore drilling activities. It is intended to incorporate this information into the Commission's final report and use it to inform the general public on offshore environmental issues as viewed by experts. This input to the report is not to be considered as a formal brief or submission to the Commission but will be identified as a response to a specific request made by them.

The Commission decided to include a relatively brief section to provide a perspective on the degree of hazard presented by offshore activities and general conclusions on promising directions for research and development. To this end, the Commission believes that three general subject areas, notably fisheries, seabirds and countermeasures, should be included in this report. The Commission is particularly interested in Environment Canada's point of view on potential for harm to seabirds with specific reference to those seabirds which are of economic importance. They requested a description of countermeasures, techniques and equipment along with a general commentary on the capabilities and limitations of the equipment. The Department of Fisheries and Oceans was requested to provide information on potential impacts to fish stocks, fishing grounds, and fishing gear with particular reference to oil spills.

## 1.1 Chronic and Accidental Hydrocarbon Discharges

It has been estimated that annually some four to six million tonnes of petroleum enter the world's oceans through runoff, operational discharges, spills, natural seeps and atmospheric fallout. Land-based sources such as urban and river runoff contribute the largest portion; roughly one-half, while routine and accidental discharges from offshore exploration or production facilities account for about 4%.

It has been reported that 172 offshore oil and gas well blowouts occured worldwide during the period 1956-1980. The major causes have been attributed to human error, equipment failure and the presence of unexpected high pressure zones in the strata being drilled. Roughly 49% of these incidents occurred during the exploration phase, 22% during development drilling, 19% in production and the remaining 20% are attributable to workovers and well completion operations.

While the quantitative risk of oil spillage is greatest during production due to the nature of the operations and to the quantities of oil available, the actual incidence of blowouts is greater during

exploration. These types of incidents are also often more difficult to control and have more scope for environmental damage. In the case of drilling or production accidents, as opposed to ship related spills, we are fortunate in knowing beforehand the exact location of the oil discharge and are thus able to expend considerable effort in developing a state of preparedness to deal with the problem. Protection priorities, currents, ice patterns, and potential spill trajectories can all be studied before any emergency event. Although the sum total of oil discharged from a blowout is generally large relative to a ship or batch spill, the amount of oil released each day is relatively low and, therefore, a more coordinated and efficient use of resources can often be employed during containment and cleanup activities.

Roughly 180 exploratory delineation wells have been drilled off the east coast of Canada to date. There have been no reports of total loss of well control, although a number of potentially dangerous situations have arisen over the the fifteen year drilling history. The most notable among these have been the following:

(1) In August, 1971, the drill barge "Typhoon" began drilling the Lief E-38 well off Labrador. The vessel was forced to abandon a damaged blowout preventer on the uncompleted well as a result of a combined threat of icebergs and a series of violent storms during October of that same year. This first well off Labrador was not properly sealed and abandoned until August, 1973.

(2) During 1975, the "Sedco 445" was blown off the Snorri J-90 well off Labrador during a hurricane damaging the blowout preventer. This occurred after drilling had reached the 10,500 ft. level and had penetrated hydrocarbon bearing strata. The well was finally abandoned in September, 1976.

(3) On November 26, 1981, the bulk carrier "Euro Princess" drifted to within 550 metres of the "Rowan Juneau" drilling for Mobil Oil off Sable Island. The rig was abandoned by her crew during the incident.

(4) The "Ocean Ranger" incident, February 1982.

## 1.2 Fate and Effects of Petroleum in the Marine Environment

Petroleum, whether it be crude oil, condensate, or gas, is a extremely complex and variable mixture of organic hydrocarbons containing thousands of compounds. Of these, hydrocarbons are the most abundant, accounting for 50 to over 95 percent of the total composition. Crude oil, for example, may contain lighter fractions similar to gasoline, medium weight components such as diesel and stove oil, as well as heavier tar or wax fractions. To date, the oil found

off the Canadian east coast may be described as 'light and sweet'. Light and sweet refer to the relatively high proportion of short chain hydrocarbons present and the absence of sulphur compounds. Gas discoveries have encountered sweet wet gas; that is, gas existing in combination with relatively large quantities of gas liquids and in the absence of sulfur.

Regardless of their actual environmental effects and economic impacts, oil spills are aesthetically repugnant and have become a symbol and constant reminder to the public of marine pollution in general. Once released into the marine environment, the fate and resultant effects of oil are dependent on a number of factors including the chemical and physical properties of the spilled oil, the volume spilled, the location of the incident, prevailing currents and weather conditions, the presence of ice, the type of spill (batch or continuing discharge) the potential for the formation of emulsions and the resources at risk, such as seabirds, fish spawning grounds, marine mammals, shellfish beds and fish concentrations. Minimal environmental damage would be expected to result from an open ocean release of light crude or gas and condensate under weather conditions favouring natural dispersion and evaporation. Release of a heavier oil into a sheltered bay during conditions favouring incorporation into sediments and contamination of low energy marsh areas is a completely different matter and might require decades to recover (witness the "Arrow" incident near Chedabucto Bay, N.S. and the Amoco Cadiz spill in Brittany).

## 1.3 Other Environmental Hazards

While oil spills undoubtedly pose the greatest environmental hazard to biota as a consequence of offshore exploratory drilling, there are several other significant sources of risk. In addition, there are several risks that relate to the utilization of biological resources. While oil spills, because of their dramatic nature and popular interest, tend to be the focus of environmental risk offshore, the cumulative effects of the other risks (which tend to be chronic in nature and widespread) may in fact be greater.

### 1.3.1 Risks to Biota

Water-based drilling muds (and their associated drill cuttings) pose a potential threat to seabed biota because of heavy metals and sedimentation. Impacts are generally restricted to the immediate area (i.e. 1000M radius) of drilling platforms.

Dispersants, used as an oilspill countermeasure, can in themselves be toxic to marine life. New generation dispersants, having lower toxicity, can be used at lower rates and therefore have an application in environmental protection (i.e. protection of seabird colonies, concentrations of flightless birds, protection of fish-spawning beaches, etc.).

High energy explosives used occasionally in seismic surveys are lethal to fish and marine mammals and significant kills can result if large charges are used in areas of high concentration of biota.

Noise associated with vessel traffic, icebreakers, and drilling platform operations can have negative effects, particularly on marine mammals.

### 1.3.2 Risks to Resource Utilization

Exclusion zones around drilling platforms and formal shipping lanes can preempt fishing activity and have the effect of reducing catches or increasing fishing costs. Their significance relates to the areal extent of preemption and how productive the area is for fishing. Present levels of offshore activity present little problem.

The loss of drilling and associated debris from offshore platforms and supply vessels has proved to be a major concern to offshore fishing interests in the North Sea and in the Gulf of Mexico. As is the case for exclusion zones, present levels of drilling activity pose low levels of risk.

Supply boat movements have the potential to interfere with fixed fishing gear, particularly in inshore settings. As well, there is potential for some conflict with inshore fishing activity per se. The operation of seismic vessels similarly could impact upon inshore fisheries. As well, because of the required "wide berth" associated with seismic surveys, there could be some interference with offshore fishing activity. To date, the east coast fishery has experienced only isolated incidents. Increased offshore activity could significantly increase the frequency of such incidents.

In addition to the biological effects of spilled oil outlined earlier, there are several risks that could be imposed upon fish harvesting, processing, and marketing. Tainted fish catches could result in lost earnings by fishermen. Tainted fish products, or even suggestion of same, could result in loss of income by fish processors and even lost or damaged markets for the product. The fouling of fishermen's gear represents a direct economic cost (i.e. cleaning or replacement) or an

indirect loss resulting from his inability to fish (i.e. lost income). The latter risk can also result from removing fishing gear from the water in anticipation of fouling.

## 2. ENVIRONMENTAL HAZARDS POSED TO FISH AND FISHERIES BY EAST COAST OFFSHORE OIL EXPLORATION

### 2.1 Introduction

The fishery represents an economic and social mainstay of Atlantic Canada. In 1981, the total catch of all species of fish from Canada's east coast fishery (i.e. NAFO Convention Area) was 2.77 million tonnes. Canada's share of that catch was 1.21 million tonnes and this represented a landed value of nearly $565 million and a marketed value of approximately $1.28 billion. In relation to Canada's fisheries generally, the east coast fishery represented 85% of its total landings, 66% of its landed value and 67% of its marketed value. In 1981 the fishery on the east coast employed some 54,000 in the primary sector (i.e. registered fishermen) and a further 22,000 in the secondary sector (i.e. fish processing).

The productivity of Canada's east coast fishery is directly related to the large areal extent of the continental shelf extending seaward from the coastline. It is this broad expanse of continental shelf that is likewise found to be attractive to the oil and gas industry in their resource development endeavors. Thus the fishing industry and the oil and gas industry are brought together. The future multiple use of the continental shelf by two industries that are both essential to the economic well-being of Canada will require considerable vigilance and forethought so as to ensure that their interests do not conflict. If cooperation does not occur, conflict is inevitable. This potential conflict could involve direct interference with both the catching and processing sectors of the fishing industry as well as posing a threat to the very supply of raw material for that industry. Generally speaking, the hazards posed by the oil industry's exploration activities off Canada's east coast come both from the scheduled activities (i.e. effluent discharges, vessel traffic, preemption of space, etc.) as well as the unplanned occurrences (i.e. fuel oil spills, blowouts, debris, etc.). Clearly, the severity of impact on the fishery from these activities and occurrences depends on their areal extent and frequency of occurrence. For the most part, it is probably safe to say that, given the present rather scattered distribution of exploratory drilling activities off the east coast, none of the impacts from planned activities is either unmanageable or unacceptable. It is important to remember that this situation could change, however, should exploration activities increase significantly. Similarly, the various unplanned events usually associated with east coast exploratory drilling have not, to date, posed a significant threat given the low level of activity overall. Here again, this situation could change with a dramatic increase in overall activity. The spectre of an oil blowout, particularly in

ice-infested waters, is always present and of real concern despite the present low level of drilling activity.

In the following sections the risks imposed upon fish and fisheries will be evaluated on the basis of our present knowledge and this assessment will consider the various unplanned-for as well as the scheduled activities associated with exploratory drilling.

## 2.2 Oil Spills

Generally, spills of hydrocarbons, resulting from exploratory drilling activities, will involve either small to moderate losses of fuel oil, during its transfer from supply boat to the drilling rig, or moderate to large discharges associated with an uncontrolled oil blowout.

Our ability to measure and predict the impacts of an oil spill on a given population is generally limited by: (1) our ability to mount sufficiently extensive sampling programs; and, (2) the overwhelming natural variability inherent in animal populations. As a consequence, our ability to measure and predict impact decreases substantially as we move from consideration of the individual organism to consideration of the population, community and ecosystem.

Generally, our knowledge of impact of oil spills at the individual organism level comes from laboratory oriented toxicology studies where experimental design is generally quite extensive. On the other hand, our knowledge of the effects of oil spills at the population, community, and ecosystem level is usually based on case history study of large oil spills. In most of these studies experimental design is usually wanting (i.e. no baseline data collected pre-spill, no control site, etc.). Recently, we have seen some of the results that can be obtained from carefully designed experimental oil spills (i.e. CEPEX, Loch Ewe, MERL and BIOS) and these studies have provided a good insight into potential field impacts.

It is difficult and often misleading to generalize the effects of spilled petroleum hydrocarbons upon marine biota. Almost every oil spill is different in its behavior and effect. Some of the variables that have to be considered for each spill include: (1) type of oil; (2) duration of the spill; (3) weathering characteristics; (4) spill trajectory; (5) fate (surface slick, emulsion, tar balls, incorporated into sediment, etc.); and (6) time of year, etc. The reader is therefore cautioned that the following impact information on various components of the marine ecosystem is generalized and somewhat simplified and quite often represents our incomplete knowledge of the subject.

### 2.2.1 Plankton

Plankton are tiny plant (phytoplankton) and animal (zooplankton) life forms that form the basis of most marine

food chains. Relatively low concentrations (i.e. less than 1 ppm) of petroleum or petroleum-type hydrocarbons are reported generally to be toxic to both phytoplankton and zooplankton. Plankton are widely distributed and dispersed throughout the upper layers of the water column and it is expected that current-induced drift would rapidly replace any affected populations. The effects of suppressed primary productivity, possibly caused by an oil spill, upon subsequent fish stock biomass will likely be undetectable or even negligible. Observations at oil spill sites also suggest that effects will be localized, minimal and transient. Nevertheless, large concentrations of oil retained in shallow coastal embayments, especially those having low circulation, can be expected to have localized impacts on plankton populations. Localized impacts can also be anticipated on ice associated or epontic planktonic communities in areas where substantial quantities of oil becomes entrapped under ice for extended periods. In general however, impacts, in both cases, should be restricted to discrete areas of high level contamination.

### 2.2.2 Macrophytes

In addition to a more commonly recognized role in providing substrate and shelter for a variety of animal life, seaweeds are believed to play an important role in the productivity of inshore environments in northern waters. Stranding large amounts of oil in intertidal or shallow sub-tidal waters can be expected to have a direct impact on seaweeds. However the extent and duration of such impacts would likely be slight - especially along unprotected high-energy shorelines. The impact probably would be comparable to that associated with the annual ice-scouring of marine plant communities in northern climes. Of more interest in highly impacted areas is the potential for the alteration of functional relationships between different interacting species. For example, after the "Tampico Maru" spill, extensive kelp beds developed in the absence of grazing herbivores. Also, following the "Torrey Canyon" spill, dense growth of green and brown algae developed as a result of the mortality of large numbers of grazing invertebrates. Such effects would, in general, be expected to be quite localized but they represent marked changes in shoreline ecology which could persist for several years.

Of greater interest are concerns resulting from major oil spills on low-energy (i.e. protected) shoreline areas, especially salt marshes. Major perturbations in salt marshes are important since such areas are highly productive, form the basis of detrital food chains, provide breeding and nursery

grounds for fish and wildlife and generally act as sediment and nutrient traps for surrounding inshore ecosystems. Damage to salt marshes has been documented at a number of major spills including the "West Falmouth" spill in Massachusetts, the "Arrow" spill in Chedabucto Bay, Nova Scotia and the "Amoco Cadiz" spill in France. Impacts on salt-marshes, as well as other low energy environments, will depend on such factors as type of oil, sediment characteristics, weathering processes and wave and current action in the immediate area. The extent of major damages would in general be quite localized but case histories to date indicate that ecological processes may be altered to varying degrees for several decades.

### 2.2.3 Zoobenthos

Benthic invertebrates are usually protected from oiling by the water column over them. However, large mortalities can be expected in shallow water communities, as in intertidal areas. Also, in highly impacted areas - as discussed in the section on macrophytes - there arises the potential for the alteration of functional relationships between plant and animal life. Adverse impacts on intertidal populations were documented at such major spills as the "Amoco Cadiz" in France as well as the "Ixtoc I" blowout in the Gulf of Mexico and the "Tsesis" spill in the Baltic. Sub-tidal populations of animals would generally be exposed to much lower concentrations of petroleum and thus be impacted to a lesser degree. In reference to the Canadian East Coast, shellfish, including commercially important species of bivalves inhabiting shallow sub-tidal waters could be damaged. On the other hand, adult lobsters, which appear less sensitive to petroleum and are commonly taken in 5-10 meters of water, would less likely be harmed. Intertidal areas are probably most sensitive to heavy oiling, and sediments containing high concentrations of petroleum, such as occurred at the site of the Arrow spill in Nova Scotia, can be expected to have adverse effects on some species of sediment dwelling organisms for several years.

### 2.2.4 Adult Fish

Laboratory studies indicate that acute toxic effects are possible in the immediate area of an offshore oil spill but the potential for measurable impact on fish stocks is generally viewed as being slight or negligible. A variety of sublethal effects have been demonstrated at the biochemical and cellular level in fish species such as cunner, cod and flounder exposed to relatively high concentrations of petroleum for several weeks. It is unlikely that minor perturbations in tissue biochemistry are of consequence but effects such as

pathological changes in gills, liver or eye-lens tissue would, depending on the degree of damage, be considered as deleterious. Significant toxic effects should, in general, be localized and limited to pelagic or benthic species inhabiting highly contaminated intertidal and shallow sub-tidal environments. Although effects would likely be quite localized, it is reasonable to assume that heavily contaminated intertidal sediments will have direct adverse effects for more than a year in benthic species such as flatfish. In addition, indirect effects upon groundfish are possible due to direct adverse effects upon sediment dwelling organisms which represent a food supply.

### 2.2.5 Ichthyoplankton

Eggs, and especially larvae, are proported to be much more vulnerable to oil than adult fish. These life forms may be less capable of detoxifying petroleum hydrocarbons, are not mobile enough to avoid exposure, and may develop at or near the surface where oil will be found in greatest concentrations. Natural mortality of larvae at the population level, (i.e. can be high, in the order of 1-10% daily). It is indicated, therefore, that large numbers of larvae would likely have to be destroyed by an oil spill before seeing a measurable change in adult fish populations. For this reason, the potential for measuring impacts on recruitment in fish stocks in the offshore seems minimal. However, the possibility exists for significant measurable impacts on stocks spawning in discrete, shallow water areas, especially if such areas are confined and have poor water circulation.

### 2.2.6 Marine Mammals

Information on oil impact for marine mammals is still limited because there have been few definitive experimental studies conducted to date. However, it can be said that because of their life habits the potential exists for many marine mammals to come into contact with oil. This applies especially to northern or ice-infested waters, where by virtue of their habits and rearing of young, both adults and young run the risk of encountering oil entrapped under ice or in leads. Also the colonial habit of most seals and some other marine mammals increases this risk.

Short term experiments carried out with seals indicate that impacts may be minimal, even in the case of exposures to relatively high concentrations of oil. Possible effects, however, include ingestion of oil droplets during grooming, loss of thermal insulation and/or waterproofing as a result of

coating and irritation of eyes and exposed mucous membranes. Eye irritations were reported after the "Arrow" spill and after a diesel oil spill off Alaska. It is difficult to speculate on long-term effects on physiology and behavior in animals coated with relatively large concentrations of oil, but in view of the results obtained after heavy oiling of young seals it is unlikely that the slight soiling of fur would have a significant effect on survival. In this regard, it is of interest that oiled individuals among a population of elephant-seal pups on San Miguel Island survived and later dispersed in a normal manner. Ice can form natural barriers protecting seals from oil, but large quantities of oil entrapped in leads in pack ice could be important in contaminating species such as harp seals. However, seal populations are widely distributed and contamination of any species would likely be restricted to a small proportion of the total population.

Marine mammals (to a greater extent than fish or invertebrates) have efficient detoxification systems for the metabolism of hydrocarbons. It is therefore unlikely that the ingestion of small quantities of oil would seriously harm this group of marine organisms.

Concern has been expressed that the gill rakers of baleen whales may be coated and damaged if they continue to feed in waters heavily contaminated with emulsified oil particles. The significance of this to overall food gathering and metabolism of the animal is likely to be minimal, in that it has been demonstrated that there is no long-term interference with filtering or food trapping functions. Also questions have been raised about the use of oil contaminated leads in polynyas by Arctic species of narwhals and white whales. Like seals, whale populations are widely dispersed and localized contamination of any species would likely be restricted to a small proportion of the total population.

Whether marine mammals possess the capability to avoid oiled waters is still somewhat of an open question. Recent studies suggest this capability in bottlenosed dolphins. However, field observations indicate that marine mammals do not necessarily avoid oiled waters, even if they do possess this capability.

### 2.2.7 Summary on the Effects of Petroleum Pollution on Marine Life

Present evidence suggests that oil pollution may have serious local and temporary consequences, but they are no greater, and generally less than natural fluctuations in populations. Considering local impacts, coastal benthic communities are vulnerable and recovery from spilled oil could be relatively slow, especially in cold temperate and arctic environments. Local breeding populations of many organisms

including fish larvae may be impacted especially in confined inshore waters. In general, however, populations of phytoplankton, zooplankton, adult fish and marine mammals are not considered to be in serious peril. Most damage will occur in coastal areas rather than in the open sea.

### 2.2.8 General Statement on Knowledge Gaps

Although the evidence indicates that the presently measurable effect of petroleum pollution will be more or less localized or at the individual organism level, there is a general consensus among experts that there is a need to gain a better understanding of the dynamics of marine ecosystems in general, so that we will be in a better position to evaluate possible subtle, indirect effects of petroleum as well as other pollutants. Our knowledge of the fundamental processes of marine ecosystems is marginal, but in recent years major advances have been made. It is hoped that in the foreseeable future, effects on biological systems will be measurable and predictable by the application of modern ecosystem theory.

A significant level of ecosystem stress, no matter what its cause, should affect a number of ecological parameters such as community diversity, stability, biomass and production. However, variability being a common feature of marine ecosystems, the problem lies in being able to discriminate the effects of pollutants from natural fluctuations in animal populations. This weakness in our ability to "see" the impact because of natural "noise" doesn't mean that the impact doesn't exist. Individual organisms respond to sublethal stress long before effects become measurable at the population or community level. Thus biochemical, physiological and pathological studies on individual organisms can provide early warning signals for potential impacts at higher levels of biological organizations.

There is presently a need to develop simple indices for assessing potential areas of impact at major oil spill or offshore petroleum development sites and to extrapolate from these indices what happens at higher levels of biological activity. Future emphasis should also be given to obtaining ecological data which can lead to a better understanding of the structure and function of ecosystems and a better capability for predicting and quantifying impacts. Any regions slated for intensive hydrocarbon development have a potential for catastrophic spills such as blowouts as well as chronic inputs of hydrocarbons and such areas should be the focus of special studies.

It is difficult, however, to suggest whether future ecological studies in the open oceans, should take priority over studies in coastal waters, the area which has been consistently shown to be most heavily impacted by catastrophic oil spills. It would presently seem judicious to attempt a balance between the two. Also, to be of most benefit it is important that study sites not be too rigorously circumscribed by "artificial" project or administrative-type boundaries.

The present weakness in our ability to predict, and subsequently measure, impact at the population or ecosystem level points our the value of effects monitoring at the individual organism level. Currently efforts are underway, in a number of quarters, to develop appropriate monitoring indices.

## 2.3 Drilling Fluids

At present, water-based drilling muds are used exclusively offshore Eastcoast and the Arctic. The trace elements contained in these drilling muds may have cumulative toxicological effects if retained in sediments.

Oil-based drilling muds have not been used to date in Canadian waters. There are, at present, at least two industry proposals for use of oil-based muds offshore Eastcoast. In general, use of oil-based muds is of greater concern than that of water-based muds. Use of diesel oil-bored muds is of particular concern because of the toxicity associated with aromatic compounds. Extensive use of diesel oil-based muds could lead to significant but localized impacts upon zoobenthos. Low-toxicity, mineral oil-based muds, while of less concern, are none-the-less problematic. Use of mineral oil-based muds result in less significant impacts and approximates that associated with water-based muds.

The accumulation of drill cuttings and other solids around platforms could have localized effects on bottom dwelling species. Highest concentration would be expected in the vicinity of platforms, but mixing and transport processes generally disperse and dilute the mud components. Extensive studies at an offshore petroleum development site in the Gulf of Mexico indicated that drill cuttings were mostly found within approximately 4 km of drilling installations with the highest concentration occurring in the immediate area of platforms. Normal, slightly coarser sediments were noted within a radius of 4 km from the platforms.

Studies on the effects of drilling muds in the North Sea and the Gulf of Mexico have shown localized impact on benthic communities, both from sedimentation and by oiling. These impacts are found, however, primarily within the immediate vicinity of drill platforms, and have not been found to have measurable impact on pelagic organisms.

## 2.4 Dispersants

Oil spill dispersants are permitted for use as a countermeasure under certain conditions, for instance, to prevent impacts on 'sensitive' shorelines, bird-colonies, seal-rookeries, important spawning grounds, etc. Early dispersants were themselves hydrocarbon in nature, and were highly toxic, giving rise to high mortalities in marine biota after their use, as during the "Torrey Canyon" incident. More recent developments have resulted in dispersants with much reduced toxicity, while still retaining their dispersing effectiveness. In addition to their low level of toxicity, they are degradable by various species of marine organisms including microbial life. Oil spill dispersants increase the levels of hydrocarbons dissolving in water and this can result in transient increases in toxicity at the point of application, before the 'dissolved' hydrocarbons are diluted and dispersed into the water column. Once in the water column, petroleum hydrocarbons are degraded and assimilated over time by various types of microbes. However, the time of degradation of small oil particles, which continue to drift in the water column or filter down into sediment, has not been well established for arctic and subarctic environments.

## 2.5 Marine Seismic Surveys

The principle method for exploring hydrocarbon-bearing rock formations, either on land or beneath the world's oceans, is the generation of shock waves (i.e. seismic waves) which bounce off the various layers of rock and return to the surface, where they are recorded by sensitive instruments. The most commonly used sources of energy for the creation of artificial shock waves, in the Canadian offshore, are non-chemical types, the most frequent being compressed air. Less frequently used are the chemical explosives.

Underwater shock waves resulting from the detonation of high energy chemical explosives are potentially lethal to fish in that they can result in the rupture of the swim bladder and other body organs. Shock waves have also been postulated to be lethal to marine mammals and sublethal effects can result in damage to their auditory system and/or abnormal behavioral patterns which may affect post-natal survival of young.

In contrast to the lethal effect of chemical explosives, when used to generate shock waves, seismic waves produced by non-chemical means such as air guns have proven to be relatively harmless to fish. Thus it is extremely unlikely that they would cause any gross damage to marine mammals.

Today, the vast majority of conventional marine seismic surveys are conducted using non-chemical explosives as the primary energy source. The non-lethal aspect of shock waves produced by non-chemical explosives makes them the preferred seismic energy sources relative to the protection of fish and marine mammal resources.

## 2.6 Noise

Vessel traffic associated with hydrocarbon production and transport in the Arctic has been shown to affect marine mammals, in two ways: by physically impinging on individuals both in open water and while breaking ice, and by interfering with their sound production and hearing. It is speculated that similar disturbances could occur in relation to oil and gas exploration on Canada's east coast.

Observations to date suggest that although the potential for interference with marine mammals as a result of noise from offshore drilling and associated vessel traffic is real, such disturbances should not cause seals or whales to abandon important areas of their habitat. In fact, whales are commonly observed in close proximity to drill rigs on the Grand Banks and off the Labrador coast, apparently showing no signs of a fright reaction.

At present there is a lack of definitive data on levels of noise which may cause the above effects.

Generally, fish will display a fright reaction to sudden noise. However, fish will quickly acclimate to the constant level of noise produced by a drill rig since they are commonly found beneath the platforms.

## 2.7 Waste Disposal

The disposal of sewage and garbage, which is generated as a result of the normal drilling operations, is well regulated in Canadian waters. Human sewage is either treated, as on board drill ships, or discharged directly into the ocean. In both cases, sewage is diluted quickly by the receiving water, and as such, the discharge of sewage from rigs is not considered to have a significant negative impact.

Flammable domestic wastes are required to be incinerated while the ashes and all other garbage are transported to shore for land disposal. Toxic chemicals must be brought to shore in safe containers and disposed of in approved land sites.

## 2.8 Effects on Fishing Industry

### 2.8.1 Normal Operations (Expected Events)

#### 2.8.1.1 Exclusion Zones

In Canadian waters where hydrocarbon exploration and development are administered by the Canadian Oil and Gas Lands Administration, an official safety zone of 500 meters in all directions of the platform or 50 meters beyond the anchor pattern, whichever area is greater, is under regulation. Thus, the existence of drilling rigs or production platforms consitutes a *de jure* loss of access to the fishing industry. The total acreage involved in exclusion zones varies extensively and is controlled by such factors as size and number of commercial fields, and the phase of development. Exploration usually involves a few rigs scattered over a large ocean area so that the resulting exclusion zones are both small and temporary. Lost fishing areas resulting from production platforms, on the other hand, may be somewhat larger, since these platforms tend to be more numerous and clustered. In either case, exclusion of fishing activities in the vicinity of offshore rigs or production platforms, while being significant in a localized sense, should not have widespread significance.

#### 2.8.1.2 Drilling Debris

Apart from the concern for their gear becoming fouled by oil resulting from an accidental spill, fishermen frequently raise a concern for submarine debris on which nets and other gear may become entangled. A major difficulty in the North Sea was the occurrence of debris around pipelines as a result of the trenching, pipe-laying, burying and rock dumping operations. In the case of drilling platforms, most, if not all, of the debris occurs within the exclusion zone and thus interference with fishing

operations is avoided during active drilling. Once single wells are abandoned, however, hitherto safety zones containing drilling debris become hazards to fishing activities. Fishermen in the Gulf of Mexico maintained that there was much abandoned or jettisoned equipment associated with offshore oil operations. Such hazards, in the context of such large fishing areas as the Grand Banks, will be localized and strict regulation can reduce the local impact.

2.8.1.3 Conflict with Gear

With increased vessel traffic associated with oil and gas exploration, the potential for conflict between this activity and traditional fishing patterns has risen. The nature of the conflict centres around the damage or loss of fishing gear which results ultimately in lost income to the fishing industry.

While supply vessels which routinely service the drilling rigs present no real problem to mobile fishing fleets (i.e. supply vessels can take evasive action to avoid fishing vessels), seismic vessels can interfere with both offshore mobile gear and inshore fixed gear. Vessels conducting seismic surveys normally tow in excess of 1000 m of "listening" cable and must maintain a precise course and speed throughout each survey line. For this reason, seismic operators are reluctant to alter course once they have begun to "shoot a line." Similarly, once a trawler has set its gear, it is difficult for the vessel to manoeuvre quickly. Thus, gear conflict could result when these two types of vessels are working in proximity to one another. A few such incidents have been reported by Nova Scotia fishermen. In one case, an otter trawl had to be cut loose when it became entangled in seismic equipment. In another incident, several Bay of Fundy fishermen (five were involved) lost lobster traps when a seismic vessel steamed through their grounds.

Although the potential for gear conflict exists and actual cases have been documented, the number of incidents in Canadian waters are low. This can be attributed in part to a well developed communications network, and in part, to

the low density of vessels of all types in relation to the large expanse of ocean in which they work.

#### 2.8.1.4 Positive Impacts

The onset of oil and gas exploration in Canadian offshore waters has been a boom to the fishing industry by providing much needed recording stations for weather and improved communications links. Indirectly, offshore exploration and development leads to an improved search and rescue service.

### 2.8.2 Accidental Events

#### 2.8.2.1 Fish Tainting

Tainting, that is, the imparting of an oily off-flavor to commercial species, is a well documented occurrence in cases where both shellfish and finfish have come in contact with hydrocarbons from oil spill incidents. Mobility appears to be the key factor in governing the probability of a commercial species becoming "contaminated" by oil. Shellfish, which generally lead a sessile or sedentary adult life, are more susceptible to tainting as are finfish caught in oiled nets or retained in nets which are subsequently oiled. It seems unlikely, however, that fish, at large in the open ocean, will pick up sufficient oil to become tainted.

Very little systematic research has been undertaken on the subject of tainting by oil. The area of research in this field, which is most neglected and deserving of more attention, is a definitive evaluation of the maximum concentration of different kinds of petroleum in water in which fish can reside without picking up petroleum-types of flavors.

Avoidance of direct contact with oil does not necessarily eliminate the problem of tainting - at least where public perception is concerned. Buyers may be reluctant to purchase fish caught in areas where there has been an oil spill even though the catch was not in direct contact with

oil. This fear of tainting can have a direct impact on the income of fishermen locally or effect the markets of large companies depending on the scale of the spill.

At present there are no established standards or guidelines for rejecting contaminated catches apart from the visible presence of oil. This situation is aggravated by the subjective nature of taste perceptions. As a result, there has been no uniformity to the application of closures and confiscations, to date.

#### 2.8.2.2 Fouled Gear

It is reasonable to suggest that virtually every major discharge of oil, whether as a result of blowout, transportation accidents or bilge-water disposal has resulted in fishing gear becoming partially or wholly coated with oil. Lighter oils and refined hydrocarbon products do not pose a great threat in that ocean turbulence tends to disperse these oils quickly while general handling of "contaminated" gear causes the lighter oils to wash or wear off rapidly. Heavier crudes or residual oils, however, can liberally coat nets, ropes, buoys, boats and their crew resulting in either loss of "contaminated" gear or an expensive and time consuming cleansing operation. Most susceptible to fouling are the fixed-gear (i.e. longlines, gillnets, traps) and the infrastructure (i.e. wharves, off-loading facilities) associated with the inshore fishery. To some extent, fishermen using mobile gear (i.e. trawls, purse seines) can keep track of surface oil slicks either visually or through established communications network and thus avoid deploying their gear in areas where the likelihood of oiling is high. However, if oil is dispersed subsurface, all gear types are equally vulnerable.

#### 2.8.2.3 Contamination of Fish Plant Intakes

In the event of an oil slick moving inshore, fish plant processing-water intakes become vulnerable to contamination, which could result

in temporary cessation of production until the oil is removed and the water system cleaned. Although the large array of countermeasures available to contain and recover oil greatly reduces the risk to fish plant processing-water intakes from contamination by surface oil slicks, dissolved or suspended oil (i.e. sub-surface oil) remains a threat.

#### 2.8.2.4 Premption of Fishing Activity

Apart from actual fouling of fishing gear, large oil slicks over or near established fishing grounds has the effect of displacing fishing activities into nearby areas where the oil slick is absent. Because of the habitual nature of fishing, fishermen displaced from their traditional grounds are often uncertain of the adjacent waters in which they are forced to fish. As a result, catches may decrease and the incidents of gear conflict may increase if large numbers of fishermen are displaced into an adjacent area.

## 2.9 Research

The Department of Fisheries and Oceans (DFO) conducts an extensive research program pertaining to offshore oil and gas fisheries problems. Major studies are carried out from Bedford Institute of Oceanography, Dartmouth; Northwest Atlantic Fisheries Centre, St. John's; and the St. Andrew's Biological Station.

DFO research related to oil and gas development includes studies of the distribution of fish eggs and larvae (oten particularly vulnerable to the effects of a spill) and on the short and long-term effects of oil and oil dispersants on fish and other marine life.

In addition, a number of oceanographic study programs are being carried out by the department, related directly to oil and gas development. Among these are oil spill trajectory studies, studies of the physical fate of oil in the water column, chemical "finger-printing" of oil, wave climate studies, surface current measurements, and studies of continental shelf dynamics.

As well as its internal research program, DFO provides advice to the oil industry on the design and execution of research and baseline data collection activities. The department also supports and encourages the industry in its efforts to improve containment and cleanup technology.

Charts of coastal and offshore resources are prepared the identification of sensitive areas and show spawning grounds, concentrations of eggs and larvae, migration routes, adult concentrations, fishing efforts, gear placement and values, landed values and locations of processing plants. These maps also depict important oceanographic characteristics such as upwellings, currents, winds and waves, as well as ice conditions.

The maps provide valuable tools for the development of counter-measure strategies in the event of an accident and may also prove useful in the evaluation of compensation claims. They can be used in coastal zone planning and to identify areas that could be reserved exclusively for fisheries development.

## 3. ENVIRONMENTAL HAZARDS POSED TO SEABIRDS BY EAST COAST OFFSHORE OIL EXPLORATIONS

### 3.1 INTRODUCTION

The coasts of eastern Canada support several million breeding pairs of marine birds, comprising the majority of the western Atlantic populations of all marine bird species except Dovekie and Roseate Tern. In addition, many birds visit the continental shelf waters of eastern Canada in winter when the Newfoundland banks are the single most important feeding area for marine birds in the North Atlantic.

Most marine birds in Canada breed during June to September. In October and November there may be a general dispersal, but arctic breeders migrate southward during this period. Most birds are on their wintering grounds from November to March and a return movement to the breeding colonies takes place in April and May. During the breeding season the numbers of seabirds are augmented by a large influx of breeders, particularily Shearwaters from the southern hemisphere, and also by non-breeding Northern Fulmars from the eastern North Atlantic. Many species winter along the coasts of the Gulf of St. Lawrence and Newfoundland and some also winter in Nova Scotia.

The following account concentrates principally on marine birds. Similar considerations of risk also apply to birds that breed in freshwater habitats but move to the sea in winter.

The importance of the impact of offshore oil exploration and consequent oil spills on seabirds is biologically significant. Moreover, the birds have a high profile in the public consciousness. The effects of oil spills on seabirds are readily apparent, even to the most casual observer.

## 3.2 Numbers and Distribution of Marine Birds in Eastern Canadian Waters

### 3.2.1 Colony Location, Size and Distribution During the Breeding Season

The positions of major concentrations of breeding seabirds in eastern Canada are shown in Figure 1. The vast majority are concentrated in eastern Newfoundland (about 3 million birds), the Groswater Bay area of Labrador (about 300,000), Akpatok Island in Ungava Bay (600,000), Digges Sound (600,000), Eastern Cumberland Peninsula (620,000) and the Lancaster Sound/Jones Sound area (about 1.5 million). Regional totals are summarized in Table 1. Other major seabirds breeding colonies also occur on the west coast of Greenland, mainly north of 70°N, with a huge concentration of Dovekies ( 10 million) in the Crimson Cliffs area south of Thule.

Information on the distributions of birds foraging away from their colonies during the breeding season are only partically known. A high proportion of Atlantic Puffins and Common Murres from the colonies in east Newfoundland probably feed within a few kilometers of the shore, at least during the Capelin spawning period. However, pelagic species such as Leach's Storm Petrel and Northern Fulmar range widely and probably cover most of the continental shelf. Thick-billed Murres breeding in Lancaster Sound and Hudson Strait are known to forage up to 120 km from their colonies. In Labrador, Atlantic Puffins, Common Murres and Razorbills forage up to 40 km from their colonies on Gannet Islands.

In addition to breeding birds, numbers are augmented in summer by southern hemisphere visitors which spend the austral winter in Canadian waters. Most important of these is the Greater Shearwater of which several million probably visit the Newfoundland banks in July to September, extending as far north as northern Labrador. Smaller numbers of Sooty Shearwaters also occur north to Newfoundland, and substantial numbers of pre-breeding Northern Fulmars from the eastern North Atlantic population occur on the Newfoundland banks and perhaps further north.

### 3.2.2 Wintering Population Sizes and Distribution

The bulk of marine birds from the high Artic, birds from eastern Canada and from West Greenland, are increased by immigration from the eastern Atlantic with birds coming to Newfoundland and the Labrador Sea from as far away as Spitzbergen. The numbers of the latter are difficult to estimate. The minimum numbers probably present off Newfoundland in winter are: Northern Fulmars, 1 million; Black-legged Kittiwake, 1 Million; Common Murre, 1 million; Thick-billed Murre, 4 million; Atlantic Puffin, 2 million and Dovekie, 10 million. Actual numbers present in late winter, when ice pushes birds south from the Labrador Sea, are probably higher. Coastal waters off Newfoundland support large numbers of Common Eiders and other sea ducks throughout the winter.

Numbers of birds wintering in the Gulf of St. Lawrence, on the Scotian Shelf, or on George's Bank are generally lower than those off Newfoundland, but the Scotian Shelf and George's Bank support the bulk of the western Atlantic's Razorbills and a proportion of the population of Common Murres. Large numbers of Common Eiders winter in the Gulf of St. Lawrence and off Nova Scotia, as well as further south.

### 3.2.3 Migration Routes and Staging Areas

For pelagic birds, relatively little is known about actual migration corridors or important staging areas. The most important migration taking place wholely within Canadian waters is the movement of Thick-billed Murres and Common Eiders from Hudson Strait and Hudson Bay southward through the Labrador Sea in fall. During September and October about 2 million Thick-billed Murres, including non-breeders and young-of-the-year, leave Hudson Strait en route for Newfoundland. A large proportion of the birds particularily susceptible to oil during this period because they are flightless and on the water.

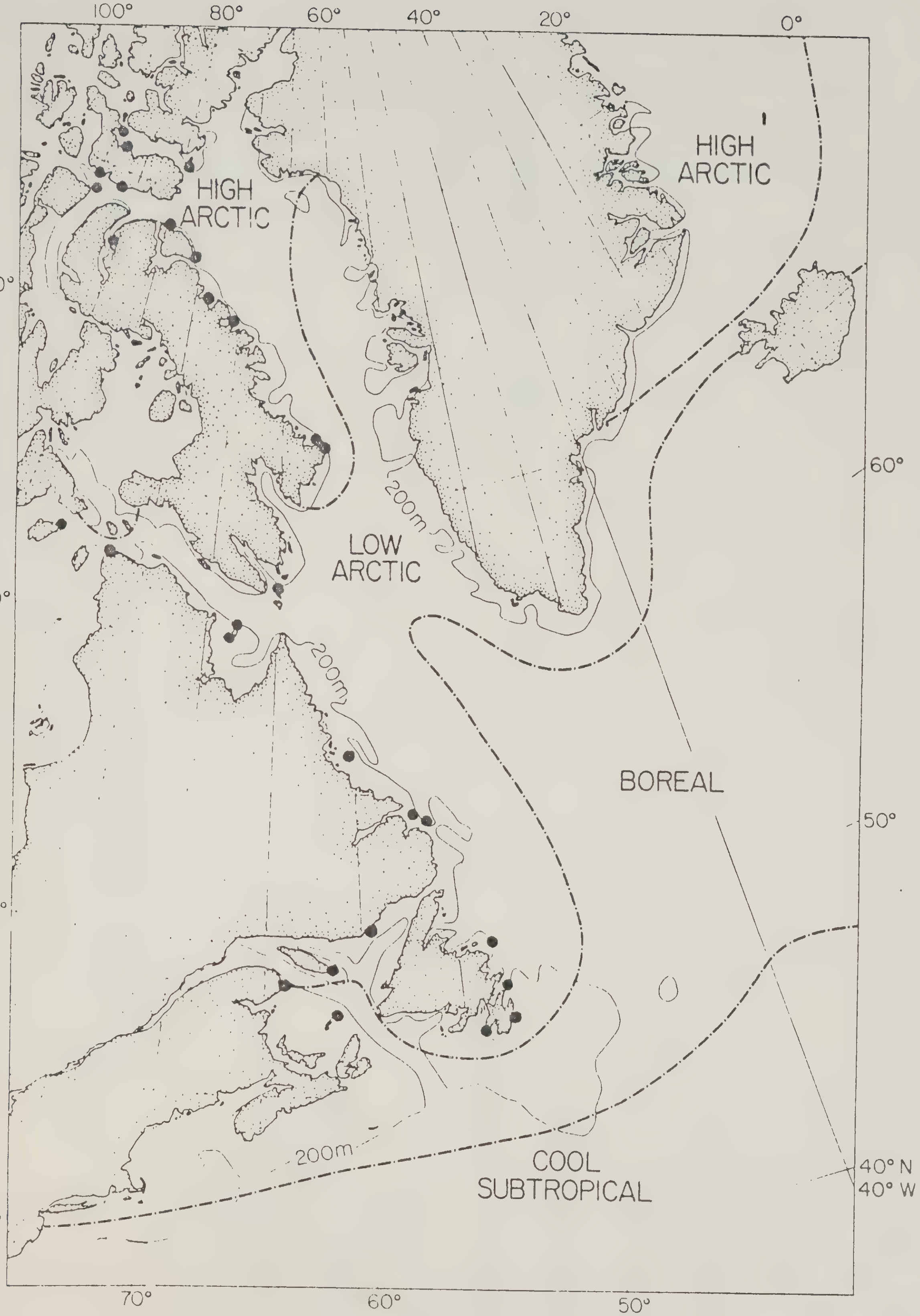


Figure 1. Major seabird colonies in eastern Canada. (●)

Table 1. Summary of marine bird populations (individuals x 1000) breeding in four areas of eastern Canada (modified from Brown, 1980).

| Species | Nova Scotia, Newfoundland and Gulf of St. Lawrence | Labrador | Hudson Strait/ Hudson Bay | High Arctic |
|---|---|---|---|---|
| Northern Fulmar (*Fulmarus glacialis*) | +1 | + | - | 720 |
| Leach's Storm Petrel (*Oceanodroma leucorhoa*) | 1600 | + | - | - |
| Northern Gannet (*Sula bassana*) | 51 | - | - | - |
| Cormorants (*Phalacrocorax carbo*, *auritus*) | 22 | - | - | - |
| Common Eider (*Somateria mollissima*) | 76 | 40 | 200 | 50 |
| Large gulls (*Larus argentatus*, *marinus* | 50+ | 10+ | 5+ | 10+ |
| Black-legged Kittiwake (*Rissa tridactyla*) | 219 | + | 10 | 180 |
| Arctic Tern (*Sterna paradisaea*) | 1+ | 1+ | 10+ | 5+ |
| Razorbill (*Alca torda*) | 8 | 38 | + | - |

| Species | Nova Scotia, Newfoundland and Gulf of St. Lawrence | Labrador | Hudson Strait/ Hudson Bay | High Arctic |
|---|---|---|---|---|
| Common Murre (<u>Uria aalge</u>) | 1023 | 112 | - | - |
| Thick-billed Murre (<u>Uria lomvia</u>) | 5 | 19 | 1340 | 1280 |
| Black Guillemot (<u>Cepphus grylle</u>) | 5+ | 5+ | 40+ | 20+ |
| Atlantic Puffin (<u>Fratercula arctica</u>) | 511 | 153 | + | + |
| | 3571 | 378 | 1605 | 2265 |

1 Present, but fewer than 1000 individuals.

Migration of Eiders occurs in two stages, with males moving in August to moulting areas around the southeast coast of Baffin Island thence to Newfoundland and females and young following in September and October.

The majority of Thick-billed Murres breeding in high arctic waters probably migrate via the coastal waters of West Greenland. The migration of Northern Fulmars and Black-legged Kittiwakes from Lancaster Sound is less clear, but waters off southeast Baffin Island and the Labrador coast support large numbers of these birds in September and October, suggesting that these are important staging areas.

## 3.3 Role of Seabirds in the Marine Ecosystem

Seabirds feed on a wide variety of marine organisms from small zooplankton such as copepods, up to herring and other fish reaching 25-30 cm in length. Rough figures for Murres in Newfoundland waters during winter suggest that they consume approximately 300,000 metric tonnes of fresh-weight biomass during the 150 days that they are concentrated in the area, a major component of which is capelin. Where commercial fishing occurs, many species take advantage of offal and trash-fish discarded by fishermen and are concentrated particularly around fishing boats. In inshore waters, sea ducks take benthic invertebrates, particularly shellfish. The figures do indicate that marine birds can have a substantial impact on the marine ecosystems.

The main predators of seabirds are people and hunting of marine birds forms a small but important part of the local economy for outports in Newfoundland, some native communities in the Canadian Arctic, and many people in West Greenland.

Between a quarter and a half a million Murres, mainly Thick-billed, and 100-200,000 sea ducks, mainly Common Eiders are shot in Newfoundland and Labrador each year. The average weight of these birds is about 1 kg (murres) or 2 kg (eiders). Hence, the equivalent value for chicken purchased in Newfoundland ($4kg), using maximum estimates, would be worth about $3.6 million. Harvests by northern communities are much smaller, probably less than 10,000 birds and the same number of eggs but constitute an important part of the diet for a few villages (Ivujivik, Pond Inlet, Cape Dorset).

## 3.4 Vulnerability of Seabirds to Drilling Operations

### 3.4.1 Noise and Other Disturbance

Experience with offshore oil developments in the North Sea suggests that noise and activity associated with the

exploration for and extraction of offshore oil deposits has little effect on marine birds. An exception to this is the siting of shore-based facilities where these affect important breeding habitat. Flaring-off of excess gases attracts birds, including seabirds, under certain weather conditions, but little mortality has been observed resulting from this effect.

### 3.4.2 Effects of Oil on Seabirds

Seabirds die from a combination of causes when they come into contact with oil. In extreme cases, oil mats the birds' feathers to such an extent that they become incapable of movement. At lower intensities birds swallow oil while preening and suffer from a variety of toxic effects, including increased metabolism and decreased digestive efficiency. The soiled plumage loses its insulating properties and hence the birds expend more energy than usual on thermoregulation. Some birds have been shown to have successfully cleaned themselves without ill effects, others found dead apparently suffered only very light soiling. We are still unable to predict the exact effect of any particular oil in any given concentration.

Species most vulnerable to oiling are those which spend most of their time sitting on the surface. This includes all the auks, sea ducks and loons. Species which spend most of their time in the air, alighting only occasionally, are much less likely to contact oil and these include Northern Fulmar, Leach's Petrel and Black-legged Kittiwake. Oil in heavy concentrations may also affect birds' food supplies either by destroying them or contaminating them. The latter applies particularly to eiders which feed predominantly on sessile filter feeders which may concentrate toxic substances. In most cases, however, direct effects on sea birds are likely to be more drastic than secondary effects operating through the food-chain.

### 3.4.3 Experience with Seabird Mortality in Relation to Major Offshore Oil Developments

Compared to the effect of chronic oil pollution levels associated with normal shipping activities, the effects of offshore oil developments in the North Sea, the most comparable area to the Canadian east coast, have been fairly small. However, significant effects have been observed over small areas, particularly close to terminal facilities. Seabird populations breeding close to the Shetlands oil terminal at Sullom Voe have been considerably reduced by several relatively small spills of the type almost certain to occur with daily oil transfers taking place. This emphasizes the importance of

siting terminal facilities away from major seabird concentrations.

A major blowout in the Hibernia area, where birds are probably denser than in the North Sea, might kill tens of thousands. A blowout of the dimensions of Ixtoc in the Gulf of Mexico would probably have a much greater impact.

### 3.4.4 Chronic and Catastrophic Oil Pollution and its Potential Effects

When considering the effects of chronic low-level pollution associated with oil developments we need to compare likely increases in oil discharge with existing background levels. In the North Sea the area was already subject to considerable oil pollution from heavy ship traffic and therefore comparisons would be difficult to make. On the other hand, in many parts of the Canadian east coast, particularly north of the Straits of Belle Isle, we are dealing with a previously uncontaminated environment. As a result, seabirds which had been free of any threat may now be exposed.

Catastrophic pollution, in the form of a major oil well blowout, can presumably be expected to occur relatively rarely. Although such an event might have a considerable impact on seabird populations in the vicinity, it seems very unlikely, given previous experiences with offshore oil developments, that such events would occur frequently enough to pose as great a threat to marine ecosystems as the routine spills and discharges associated with day-to-day operations. However, the vulnerability of seabird populations varies considerably between different areas of the eastern Canadian continental shelf. A large spill at the wrong time in the wrong place could have serious consequences for a substantial portion of eastern Canada's seabirds.

## 3.5 Potential Impacts of Major Oil Spills in Selected Areas

### 3.5.1 Hibernia

A major oil spill at the Hibernia site can be expected to move across areas on the continental slope at the edge of the Newfoundland banks that support large concentrations of marine birds throughout the year. Species particularly at risk would be, in winter, Common and Thick-billed Murres and Dovekies and in summer Northern Fulmars and Greater Shearwaters.

A worse-case scenario, involving a slick covering a thousand square kilometres, could kill 10-20% of Dovekies and Murres wintering off Newfoundland. The population consequences

of such a spill would probably be spread among all contributary populations and would take several years to replace. Relative to other areas, economic losses, in terms of lost hunting, would probably be fairly small.

### 3.5.2 Labrador Sea

A major spill occurring in the Labrador Sea would have greatest impact on seabirds in September-October when large numbers of Thick-billed Murres, Northern Fulmars, Black-legged Kittiwakes and Phalaropes (Lobipes lobatus, Phalaropus fulicatus) pass through the area. In the worst case we can envisage a large proportion of young and flightless adult Thick-billed Murres from colonies in Hudson Strait which would reduce the harvest of eggs and adults by northern communities, and probably have a significant impact on the numbers available to Newfoundland hunters. The rate of recovery from such a event is hard to predict because the effects of density-dependent adjustments cannot be measured. However, even at the most optimistic, we could not expect Thick-billed Murre colonies in Hudson Strait to recover in less than 10-20 years, and perhaps not at all.

### 3.5.3 Davis Strait

The continental shelf area in Davis Strait is most important as a feeding ground for Northern Fulmars and for the large Thick-billed Murre colony at Reid Bay, near Cape Dyer. The main danger period in this area is similar to that for the Labrador Sea, but the majority of Thick-billed Murres are believed to migrate on the Greenland side of the Strait and current patterns would probably keep the oil on the Canadian side.

In the worst case, a spill occurring off Cape Dyer in late August or September might substantially reduce the Thick-billed Murre colony at Reid Bay. Recovery is conjectural. Economic consequences would probably be small.

### 3.5.4 Lancaster Sound

The area comprising Lancaster Sound, Jones Sound and adjacent parts of Baffin Bay is the richest in the eastern Canadian arctic in terms of numbers and species diversity of marine birds. Major spills in the vicinity of the Thick-billed Murre colonies at Prince Leopold or Coburg Islands, or Cape Hay, Bylot Island could decimate their populations beyond recovery. A large spill at the mouth of Lancaster Sound in September could destroy a large proportion of the populations from all three colonies. If it spread into coastal waters off

south eastern Devon Island large numbers of Northern Fulmars and Black-legged Kittiwakes would also be killed.

Because of already declining numbers, there is no certainty that Thick-billed Murre populations in the Sound could recover if affected in a substantial way by oil pollution. Economic consequences would include reduced kills by hunters in Greenland and Newfoundland.

### 3.5.5 Scotian Shelf

This area is not thought to be as rich in seabirds as the Newfoundland banks and it is recognized that hydrocarbon finds in this area are primarily gas and condensates. A major oil spill in summer would probably affect mainly non-breeding Southern Hemisphere visitors such as Greater Shearwaters. In winter it could have a substantial impact on numbers of Razorbills; a species which is uncommon and declining worldwide. However, information on numbers and distributions is insufficient to predict what the population consequences of a spill might be.

### 3.5.6 Gulf of St. Lawrence

In such a confined area of the sea, any major spill would inevitably reach the shore. At any time of year this would mean killing large numbers of Common Eiders and in winter many other sea ducks, particularly Barrow's Goldeneye, would be affected. A spill in the area of the Gaspé Peninsula would affect the largest North American colony of Gannets at Bonaventure Island, perhaps reducing it substantially. This colony is a major tourist attraction and its value as such would diminish if the Gannets disappeared. Reduction in eiders, particularly in the estuary of the St. Lawrence, would affect the down-collecting industry in that area, with a consequent loss of income and employment.

## 3.6 Mitigation of Impact on Seabirds

### 3.6.1 Dispersants

Seabirds are likely to be a key beneficiary in the decision of an on-site commander to use dispersants to combat a particular oil spill. As far as other forms of marine life are concerned, the toxic properties of the oil are not effective until it is incorporated into the water column; the process promoted by dispersants.

An important factor in a decision to use dispersants in a given situation is likely to be the number of seabirds believed to be at risk. If the spill occurred off Labrador or at the

mouth of Lancaster Sound in late August or September the need to deploy dispersants to avoid the oiling of flightless Murres would be compelling. In other situations, where birds are less concentrated, or more mobile, the benefits to seabirds would have to be weighed against possible adverse consequences for fish larvae and marine invertebrates.

### 3.6.2 Clean-up of Oiled Birds

Many interest groups in the U.K. and North America have devoted a lot of time to developing techniques for cleaning and rehabilitating oiled seabirds. Success rates are generally rather low, depending on the initial condition of the birds, but most seabirds only come ashore when exhausted and close to death.

## 4. COUNTERMEASURES - RESPONSE, EQUIPMENT AND TECHNIQUES

### 4.1 Emergency Response

Public health, safety and environmental protection are of paramount importance in responding to and preventing oil spill emergencies. As recently as 1981, the Federal Cabinet issued an Order -in-Council known as the Emergency Planning Order which re-affirms the importance of emergency preparedness. The wide-ranging properties of oils actually and potentially spilled provide a variety of difficult problems to be solved and often a narrow field of knowledgeable experts from which to draw advice and assistance. Furthermore, long transportation routes, a cold climate, a variety of sensitive environments and overlapping jurisdictions combine to make east coast spill contingency planning, prevention and response a particularly difficult multi-disciplinary task.

The focus of the remainder of this section is to describe available countermeasure techniques and equipment along with a general comentary commentary on the capabilities and limitations of that equipment. To respond to environmental emergencies, the sensitivity of environment including resources at risk must be determined at the planning stage long before the incident occurs. To this end, the Department of the Environment has since 1975 conducted reconnaissance field studies to characterize the marine and coastal environment throughout the Atlantic Region. This work was completed in order to priorize coastal/lands marine waters as to sensitivity to contamination while considering wildlife, recreational aesthetic and other environmental values. This priorization which is needed to select and deploy appropriate countermeasures techniques and equipment cannot take place without the basic inventory of coastal characteristics and the resource capability of nearshore lands and marine waters.

A relatively large number of individuals and agencies may become involved in responding to spills in the Atlantic Region. Normally, the owner, transporter, or storer (i.e. the polluter) experiences the spill and calls on his own individual, company or agency response organization. Unfortunately, not all companies and agencies place the same level of effort on developing the contingency plans that are necessary for a timely and appropriate response to spills. Depending on spill magnitude, the polluter's response may depend, as well, on outside support from commercial cleanup contractors, from an industrial cooperative response organization (such as the East Coast Spill Response Association, Atlantic Petroleum Association, or the Petroleum Association for the Conservation of the Environment). In addition, support may come from pre-arranged government scientific advisors or researchers based in nearby universities or other academic institutions. Initial reports (hopefully via the established reporting numbers: Zenith 49000/(902) 426-6030 in the Maritimes, or (709) 772-2083 in Nfld.) of the spill incidents should be made to local, regional, provincial, or federal government agencies, depending on the circumstances and the regulatory requirements of the situation. These government agencies may respond either individually or collectively in a variety of ways by:

1) providing on-scene monitoring and assessment;

2) providing technical, environmental, social and economic advice to the incident On-Scene-Commander (OSC) and his staff;

3) taking command and control of the situation if

    a) the polluter is incapable or unwilling to carry out his responsibilities

    b) the polluter is unknown or has left the scene of the incident

    c) the safety and health of nearby residents, or the security/value of nearby property or resources are threatened

    d) the environment is not being adequately protected

A number of government agencies, including Canadian Coast Guard, Environment Canada (EPS and AES), Fisheries and Oceans, Canadian Oil and Gas Lands Administration, Ports Canada and provincial Departments of Environment have mandates which relate to oil spill response. These agencies ensure that the oil industry meets regulatory standards in the areas of contingency planning,

prevention and spill response. Government also provides a variety of support services such as training programs, research and development projects and support funding, on-scene advice and assistance when spills occur.

A number of systems are in place to provide information and assistance prior to and during oil spills. The National Environmental Emergencies Team (NEET) and, in the Atlantic Region, the Regional Environmental Emergencies Team (REET) exist as for an exchange of information and ideas on contingency planning, equipment and emergency response, and to ensure that structures are in place for adequate emergency response. The latter is a responsibility assigned by Cabinet Directive to Environment Canada.

REET is comprised of federal, provincial, municipal and industrial agencies and other organizations having legitimate roles to play in environmental emergency planning and response. At the time of a spill, the REET serves as a flexible and expandable committee of experts and agency representatives organized and coordinated to provide technical information and advice through the team chairman to the OSC on a variety of issues including environmental impacts, logistics, and public relations.

The impetus for oil transportation, exploration, processing and handling companies to respond to spills is derived partly from government legislation and regulations but also from negotiation and agreements. The oil companies have developed a mutual aid system or cooperative arrangement for training, response and equipment.

Case histories suggest that during major spills a single authority or OSC should be identified to immediately take the overall responsibility for coordination of response actions. Contingency plans normally assign one individual (and an alternate) to this extremely demanding role. The OSC may be a representative of an oil company, a government official, or an independent oil spill cleanup contractor. In the event of a spill, the OSC is responsible for decisions on actions to take throughout each phase of the cleanup operation. The OSC maintains a constant liaison with the appropriate government agencies to obtain support to provide progress reports on all aspects of the emergency.

## 4.2 Capabilities and Limitations of Equipment

There are a number of factors which have a bearing on the response strategies and the effectiveness of oil spill equipment employed off the east coast of Canada. The waters off this coast are cold and often rough, fog is common, sea ice is present in many locations for a significant part of the year, and many drilling sites are remote from sources of cleanup and containment equipment.

Rapid spreading and weathering of oil takes part in an offshore spill. Any delays in instituting cleanup actions will, therefore, increase the spread of the oil in the environment and make the cleanup more difficult and costly.

Within the Atlantic Region, there are a number of sources where oil spill response equipment such as booms, skimmers, sorbents, dispersants and tracking buoys are stockpiled. The Canadian Coast Guard maintains the largest inventory with approximately $25 million worth of equipment, followed by the East Coast Spill Response Association with approximately $8 million, the Atlantic Petroleum Association with approximately $3 million, and a number of contractors with a total inventory worth approximately $1 million.

A brief outline of the equipment presently employed on the east coast of Canada is as follows:

4.2.1 Booms

- Booms are generally the first equipment mobilized during a spill.

- A number of the booms available today are built to survive rough seas, are compactable and relatively easy to deploy. Regardless of the type of construction, however, any of the booms currently available will fail to contain oil when: water velocities exceed approximately one knot; winds are greater than 15-20 knots; sea states are above 3-4 on the Beaufort Scale. Conventional booms are also not designed to be used in the presence of ice.

- Sorbent booms are specialized containment devices which absorb moving oil slicks in a porous material such as straw or a synthetic product. Such barriers are only effective when the oil slick is relatively thin since the recoefficiency decreases significantly once the material is saturated with oil. Wave heights greater than about 0.3 m or choppy water prevents successful oil containment using this system.

- At present, the boom most widely used offshore is the B.P. Vikoma Ocean Pack. This boom is stored and deployed from a fiberglass hull and is made up of a waterfilled balast chamber and an air flotation chamber. The Vikoma is ideal for fast response, however, continuous power is necessary to sustain the boom in the deployed configuration. It has been determined through field trials that this type of boom can sustain up to a 2.5 m. wave height and 0.7 knot current. However, for most winter conditions off the East Coast of Canada this equipment would be ineffective.

- A unique fireproof boom has been developed to the prototype stage. The purpose of this device is to contain oil for in-situ combustion in close proximity to the surface release of a subsea blowout. This boom is made of stainless steel designed to withstand temperatures of approximately 1000 degrees C. Additional work is necessary to improve the resilience of this boom in offshore wave conditions. Fireproof booms cannot yet be considered part of an existing capability to deal with offshore spills.

- Booms are not generally in short supply in the Atlantic Region. The main limitation on their use relate to difficulties with deployment 200 miles at sea in other than ideal conditions, their ineffectiveness in most winter conditions, logistical problems, vessel availability and a lack of personnel experienced in operating the equipment.

4.2.2 Skimmers

- Mechanical devices to recover spilled oil are available in a variety of forms ranging from large self-contained and self-propelled vessels down to small units that can be handled and operated by a single person. These devices can be classified according to three basic principles of operation: surface skimmers, weirs and suction devices. The effectiveness of any skimming device depends on wave conditions, the presence of debris, ice and emulsions; suction-type skimmers often pick up larger volumes of water than oil which may then lead to storage/disposal problems.

- At present, the Framo ACW-400 is the state-of-the-art skimmer for offshore spills. This equipment is designed for high volume recovery of oil contained by booms and it can be operated in a wide range of sea conditions. The equipment has a capacity to process from 100 to 200 cu. m/hr depending on oil type and wave conditions. This apparatus is a self-contained unit that can be installed on a wide variety of vessels. The Framo skimmer is large and sophisticated and therefore imposes logistical and technical problems. It operates up to a maximum 2.5 m. wave height and requires 1 cm. oil thicknesses for efficient recovery.

- For nearshore operations, the Morris Industrial MI-30 skimmer has been shown to be effective in recovering contained slicks. It can be used to remove fresh or slightly weathered crude. Such small skimmers function best in relatively calm sea conditions and have limited capability to recover oil in debris infested waters. Efficient recovery necessitates 1 cm. thicknesses of oil.

- Another popular skimmer, the Oil Mop, uses a rope woven with polypropylene strands. Oil preferentially adheres to the rope mop and is squeezed off the wringing system. The Oil Mop can pick up a range of oil and the unit can function well in limited wave conditions and in the presence of some debris, but is severely limited by cold weather conditions.

- 'Slicklickers' are also widely available for spill response. They can be effective in recovering contained oil, including very viscous products, by simply transferring products on a rotating belt to a storage container. Generally, this device is limited to operations in calm water and its operating time can be hindered by slow transfer operations.

4.2.3 Slick Tracking and Surveillance

- Oil spill surveillance is usually accomplished by visual observation from aircraft, ships or by using radio-tracking buoys. Radio-tracking buoys have been designed to move under the influence of currents and wind such that they will drift with an uncontained slick.

- The Orion buoy, one type of tracking device commonly used on the east coast, contains a transmitter contained in a high impact plastic casing which sends a signal back to a receiver. The drift of the buoy can be monitored from land, sea or air. This apparatus has the obvious advantage that tracking can continue even during periods of poor visibility or darkness. Tracking is possible for up to 15 km. from a surface vessel and to 45 km. from aircraft.

- The tracking of oil contaminated ice may prove to be an important and difficult countermeasures operation off the east coast. ARGOS positioning buoys have been successfully used to track moving ice in the past. Signals transmitted from the buoys are received by two satellites on polar orbits, the data stored and relayed back to telemetry stations upon command. Modified Orion buoys can also be utilized in tracking oiled ice. Satellite imagery can also be employed, however, such techniques are susceptible to blockage by cloud cover which limits their usefulness.

- A more sophisticated method to detect and map oil slicks involves remote sensing. The sensors that have shown to be of value are: high resolution photographic camera; low-light- level television; laser fluorosensor; ultraviolet/infrared line scanner; side looking airborne radar (SLAR); synthetic aperture radar (SAR) and microwave radiometer. None of the remote sensing systems are presently

configured permanently and specifically for oil spill detecion and monitoring.

- A variety of computerized spill simulation and trajectory models are also available nationally and internationally. These models can be applied as both a planning tool and as a real-time slick prediction technique. The major inadequacy of all present models is the unreliability of input data for currents and winds.

### 4.2.4 Chemical Dispersants and Application Equipment

- Chemical dispersant products are still considered by many to be in the experimental stage and not necessarily a proven technique. Use of dispersants in the field has, in the past, not been particularly well documented and it has, therefore, been necessary to rely almost exclusively for information on small scale laboratory toxicity and effectiveness tests. Government and industry are still attempting to improve and evaluate the delivery systems and effectiveness of application of dispersants; much work also remains to be done to assess whether these products offer substantial protection to resources at risk. Dispersants should not be the first and only response action rather they are a tool of potential use when mechanical recovery methods are not feasible and if a net environmental benefit from their use can be reasonably expected.

- Chemical dispersants speed up the dispersion of oil slicks into the water column by lowering the interfacial tension between oil and water. With the application of mixing energy, the oil has a tendency to break up into small droplets and become distributed into the upper layers of the water column as an oil in water emulsion. When dispersants are applied, the resultant concentrations of oil in the water column is initially high, however, these concentrations decrease rapidly. How effective a chemical dispersant will be depends firstly on the properties of the particular dispersant, and secondly on a complex matrix of physical, chemical, biological, geographic and climatic factors which are unique to each oil spill. In cold rough east coast waters, oil rapidly emulsifies and thickens making it less succeptible to dispersion.

- A number of advantages and disadvantages associated with the dispersion of oil into the water column must be considered.

#### Advantages of Using Dispersants

1. The removal of surface oil slicks may reduce the risk of damage to waterfowl, sea mammals and private property.

2. The removal of surface oil may eliminate or reduce the quantity of oil stranded on shorelines or waterfront installations.

3. The natural rate of biodegradation of dispersed oil is believed to be accelerated by using dispersants.

4. The cleaning of oiled surfaces or work areas may be facilitated.

5. Dispersed oil is subject to subsurface currents which may carry it in a different direction than a floating slick.

6. It has long been postulated that use of dispersants will reduce a fire hazard, however, recent research has placed this theory in some doubt.

Disadvantages of Using Dispersants

1. There is generally only a brief period during which dispersants are effective against crude oil due to natural weathering processes.

2. The accelerated transfer of oil into the water column in localities that experience low flushing or water exchange rates may create unacceptable toxicity problems for marine life.

3. Unsuccessfully treated and dispersed oil may be difficult to recover by mechanical means.

4. Advantages gained by the use of dispersants at one site may be offset by the re-introduction of oil from an untreated area.

### 4.2.5 Incendiary Devices and Incineration Systems

- An advantage of incineration or burning as a disposal technique is its applicability to isolated areas where disposal on land may not be possible. Burning can also result in decreased costs and logistical requirements. The disadvantages, however, are the resulting air pollution problems and the difficulty of igniting heavy or weathered oil.

- Several helicopter transportable incineration devices are presently available including: the Saache burner, air portable pit incinerators, air curtain pit incinerators and reciprocating kilns.

- More recently air-deployable igniters have been developed for burning oil trapped on or within sea ice.

### 4.2.6 Natural and Synthetic Sorbents

- Sorbents are defined as any material which will recover oil through either absorption or adsorption.

- Generally speaking, these materials do not play a primary role in oil spill cleanup operations, and are most commonly used for final cleanup of trace amounts of oil or to remove oil fromm areas which are inaccessible to skimmers. Some sorbents are highly efficient collectors of surface oil, while others tend to release oil before and during handling and therefore create more cleanup problems than they solve.

- There are three basic classes of sorbents: (1) natural organic materials such as peat moss, straw, hay and sawdust; (2) mineral-based materials such as vermiculite, perlite and volcanic ash; and (3) synthetic organic sorbents such as rubber, polyester foam, polystyrene and polyurethane. The latter class of sorbents are most often favoured because of their greater capacity for oil per unit volume and the fact that many are re-useable.

## 4.3 Promising Directions for Research and Development

There are a number of sources of funding in Canada for countermeasures equipment research and development. Government agencies and several oil companies have ongoing programs in addition to the collective efforts of the Canadian Offshore Oil Spill Research Association and the Environmental Studies Revolving Funds.

There are good prospects for significant improvement in capability through research and development.

### 4.3.1 Booms

Equipment to apply high-pressure waterjet technology to obtain an effective oil containment and diversion capability is presently being evaluated. This type of boom may be useful in partially ice-obstructed waters and flooded mudflats.

### 4.3.2 Gelling Agents

Gelling agents have been developed by British Petroleum in the U.K. Based on the results of exploratory trials done in conjunction with the Baffin Island Oil Spill (BIOS) experiment, such products will provide the option of effectively solidifying spilled oil. The toxicity and effectiveness of gelling agents are presently being evaluated.

#### 4.3.3 Dispersants

No-mix concentrate dispersants are being developed by a number of companies. While such products seem to be considerably more effective than earlier dispersants, they also would appear to be much more toxic to marine organisms.

#### 4.3.4 Skimming Devices

The high-pressure waterjet barrier mentioned previously is being modified to produce a flushing and removal capability for cleaning oiled marshes, mudflats and ice congested waters.

#### 4.3.5 Remote Sensing

The possibility of detecting oil in and under ice using acoustic energy is being evaluated at this time.

### 4.4 Overview of East Coast Research

#### 4.4.1 Arctic Marine Oilspill Program (AMOP)

This ongoing program, currently funded at $835,000 per year, was begun in April 1977 to develop oil spill countermeasures technology for ice covered and ice congested waters. Research particularly applicable to the east coast of Canada includes:

- determination of the remote sensors most effective for detecting oil in the presence of ice;
- modification of skimmers for low-temperature use;
- development of an air-droppable oil slick igniter;
- development of an air-portable incinerator for oiled combustible materials and an air transportable kiln for burning oil in beach sand and gravel; and,
- development of Canadian technology for the aerial application of dispersants.

#### 4.4.2 Baffin Island Oil Spill (BIOS) Project

Conducted on the shores of Cape Hatt on the north end of Baffin Island, this four-year internationally funded experiment (begun in 1980) is providing valuable information on the long term effects of chemically dispersed vs. stranded crude oil on Arctic nearshore marine life and on the effectiveness of various shoreline cleanup techniques.

### 4.4.3 Offshore Dispersant Trials

The third in a series of offshore trials of aerially applied dispersants is scheduled for September, 1983. The Canadian Aerial Applications Task Force, a government/industry group, previously conducted a similar trial using fixed-wing aircraft as the spraying vehicle. The 1983 experiment will use a helicopter for that purpose and will also compare the effectiveness of new generation products.

## 5. CONCLUSIONS

The potential for hydrocarbon pollution is likely to increase with the greater activity along the east coast. The negative consequences of this pollution will depend on a number of factors such as the chemical and physical properties of the oil, the volume spilled, location, weather conditions and the resources affected. The cumulative effects of other risks to biota and to the fishing industry from activities associated with hydrocarbon exploration are also significant. It can be expected that oil pollution may have serious local, though temporary, consequences particularily for most populations on the lower end of the food chain. Coastal areas tend to be most heavily impacted. The greatest protection for seabirds comes by limiting their contact with oil. Both the location of spills and the time of the year are important factors. A number of mitigating methods designed to limit the negative effects on the environment are available and there is some promise for future improvement in capability. However, none of these are as important as prevention in the first instance.

# BIBLIOGRAPHY

## I. ENVIRONMENTAL HAZARDS POSED TO FISH AND FISHERIES BY EAST COAST OFFSHORE OIL EXPLORATION

Addy, J.M. et al. 1983. Environmental effects of oil-based mud cuttings. In: Proceedings of Offshore Europe '83 Conference.

Anonymous, 1978. A Physical and Economic Evaluation of Loss of Access to Fishing Grounds Due to Oil and Gas Installations in the North Sea, Report No. 1. Department of Political Economy and the Institute for the Study of Sparsely Populated Areas, University of Aberdeen, Scotland. 152 p.

Canada Dept. of Fisheries and Oceans. Annual Statistical Review. 1981. Volume 14, Statistics and Analysis Division, Economic Development Directorate, Department of Fisheries and Oceans. 170 p.

Clark, R.B. 1982. The impact of oil pollution on marine populations, communities and ecosystems: a summing up. Philos. Trans. R. Soc. Lond. B. 297, 433-443.

Dey, A.C., J.W. Kiceniuk, U.P. Williams, R.A. Khan and J.F. Payne. 1983. Long term exposure of marine fish to crude petroleum 1. Studies on liver lipids and fatty acids in cod and winter flounder. Comp. Biochem. Physiol. C. Comp. Pharmacol. 75C (1): 93-101.

Dickason, O.E. 1970. Alaska Peninsula Oil Spill. 27 April 1970. Center for Short Lived Phenomena Event Number 36-70, Smithsonian Institution, Cambridge, Mass.

Falk, M.R. and M.J. Lawrence. 1973. Seismic exploration: its nautre and effect on fish. Can. Fish. Mar. Serv. Tech. Rep. CEN-T-73-9: 51 p.

Fletcher, G.L., M.J. King, J.W. Kiceniuk and R.F. Addison. 1982. Liver hypertrophy in winter flounder following exposure to experimentally oiled sediments. Comp. Biochem. Physiol. 73: 457-462.

Geraci, J.R. and T.G. Smith. 1976. Behavior and pathophysiology of seals exposed to crude oil. In: Sources, Effects and Sinks of Hydrocarbons in the Aquatic Environment. Am. Inst. Biol. Sci., p. 447-462.

Geraci, J.R. and T.G. Smith. 1976. Direct and indirect effects of oil on ringed seals (Phoca hispida) of the Beaufort Sea. J. Fish. Res. Board Can. 33(9): 1976-1984.

Gilfillan, E.S. and J.H. Vandermeulen. 1978. Alterations in growth and physiology of soft-shell clams, Mya arenaris, chronically oiled with Bunder C from Chedabucto Bay, Nova Scotia, 1970-76. J. Fish Res. Board Can. 35(5): 630-636.

Gordon, D.C. and N.J. Prouse. 1972. The effects of three oils in marine phytoplankton photosynthesis. Mar. Biol. 22(4): 329-333.

Johnston, R. 1977. What North-Sea oil might cost fisheries. Rapp. P. -V. Reun. Cons. Int. Explor. Mer 171: 212-223.

Jones, J.I. and S.E. Williams. 1980. The distribution and origin of bottom sediments in Timbalier Bay, Louisiana, and the adjacent offshore area. In C.H. Ward, M.E. Bender and D.J. Reish (Eds). The Offshore Ecology Investigation: Effects of Oil Drilling and Production in a Coastal Environment. University, Houston, Texas. In: Rice University Studies: V.65 No. 4 & 5.

Khan, R.A., J. Kiceniuk, M. Dawe, U. Williams. 1981. Long term effects of crude oil on Atlantic cod. ICES Report C.M. 1981/E:40.

Le Boeuf, B.J. 1971. Oil contamination and elephant seal mortality - "negative" finding, In D. Straughan (Ed.). Biological and Oceanographical Survey of the Santa Barbara Channel Oil Spill 1969-1970. I. Biology and Bacteriology, p. 277-285. Univ. South Calif. Allan Hancock Found.

Le Moal, Y. and M. Ouillien-Monot. 1981. Etude des populations de la macrofaune et de leurs juveniles sur les plages des Abers Benoit et wracin. In Amoco Cadiz: Consequences d'une pollution accidentelle par les hydrocarbures. Publié. par Le Centre National Pour L'Exploitation des Océans, Paris, 1981.

Linden, O., R. Elmgren, P. Boehm. 1979. The Tsesis oil spill - its impact on the coastal ecosystem of the Baltic Sea. Ambio 8(6): 244-253.

Longhurst, A. 1982. Consultation on the consequences of offshore oil production on offshore fish stocks and fishing operations. Can. Tech. Rep. Fish. Aquat. Sci. 1096.

McAuliffe, C.D. 1977. Dispersal and alteration of oil discharged on a water surface. p. 19-35. In D.A. Wolfe, (ed.). Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms. Pergamon Press, New York.

McIntyre, A.D. 1982. Oil pollution and fisheries. Philos. Trans. R. Soc. London, B279: 217-225.

Mansfield, A.W. 1983. The effects of vessel traffic in the Arctic on marine mammals and recommendations for future research. Can. Tech. Rep. Fish. Aquat. Sci. No. 1186. 97p.

Nelson-Smith, A. 1968. Biological consequences of oil pollution and shore cleansing. In J.D. Carthy and D.R. Authur (Eds). The Biological Effects of Oil Pollution on Littoral Communities. Proceedings of a symposium held at Orielton Field Centre, Pembroke, Wales. Suppl. to Vol. 2 of Field Studies, London, Field Studies Council. p. 73-80.

Nordco. 1982. Study of the potential socio-economic effects on the Newfoundland fishing industry from offshore petroleum development. Rep. for East Coast Petroleum Operators Assoc. by Nordco. 68 p.

North, W.J., M. Neushul and K.A. Clendenning. 1965. Successive biological changes observed in a marine cove exposed to a large spillage of oil. Symposium, Commission internationale pour l'exploration scientifique de la Mer Méditerranée, Monaco. p. 335-354.

Ott, F.S., R.P. Harris, and S.C.M. O'Hara. 1978. Acute and sublethal toxicity of naphthalene and three methylated derivatives to the estuarine copepod, Eurytemora affinis. Mar. Environ. Res. 1: 49-58.

Payne, J.F. 1982. Metabolism of complex mixtures of oil spill surfactant compounds by a representative teleost (Salmo gairdneri), crustacean (Cancer irroratus), and mollusc (Chlamys islandicus). Bull. Environ. Contam. Toxicol. 28: 277-280.

Payne, J.F., J. Kiceniuk, R. Misra, G. Fletcher and R. Thompson. 1983. Sublethal effects of petroleum hydrocarbons on adult American lobsters (Homarus americanus). Can. J. Fish. Aquat. Sci. 40(6): 705-717.

Payne, J.F., J.W. Kiceniuk, W.R. Squires, G.L. Fletcher. 1978. Pathological changes in a marine fish after a 6-month exposure to petroleum. J. Fish. Res. Board Can. 35: 665-667.

Pearce, P.A. 1970. Arrow oil spill 13 February 1970. Center for Short-Lived Phenomena Event Number 15-70. Smithsonian Institution, Cambridge, Mass.

Penrose, W.R. 1982. Effects of oil hydrocarbons and dispersants on fish. In: J.B. Sprague et al (eds) Oil and Dispersants in Canadian Seas - Research Appraisal and Recommendations. Economic and Technical Review Report, EPS 3-EC-82-2, p. 81-86.

Petro Canada 1982. Offshore Labrador Initial Environmental Assessment

Rice, S.D., J.W. Short and J.F. Karinen. 1977. Comparative oil toxicity and comparative animal sensitivity. In D.A. Wolfe (ed.) Proceedings of a Symposium on fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms. New York, Pergamon Press, p. 78-94.

Smith, J.E. (ed.) 1968. "Torrey Canyon" pollution and marine life; a report by the Plymouth Laboratory of the Marine Biological Association of the United Kingdom. Cambridge University Press, 196 p.

South, C.R., A. Wittick, and R. Hooper. 1979. Biological bibliography of the Labrador Sea and Coastal Labrador. Dept. Biol., Memorial University of Newfoundland. Manuscript Report to Total Eastcan Explor Inc., St. John's, Nfld. 2 vols.

Straughan, D. 1971. Biological and oceanographical survey of the Santa Barbara Channel oil spill, 1969-1970. Vol. 1. Biology and bacteriology. Univ. South Calif. Allan Hancock Found.

Stansby, M.E. 1978. Flavors in fish from petroleum pickup. Marine Fisheries Review 40(1): p. 13-17.

Thebeau, L.C., J.W. Tunnell, Q.R. Dokken, and M.E. Kindinger. 1981. Effects of the Ixtoc I oil spill on the intertidal and subtidal infaunal populations along lower Texas coast barrier island beaches. In 1981 Oil Spill Conference - American Petroleum Institute Publication No. 4334. p. 467-475.

Thomas, M.L.H. 1978. Comparison of oiled and unoiled intertidal communities in Chedabucto Bay, Nova Scotia. J. Fish. Res. Board Can. 35(5): 707-716.

Vandermeulen, J.H. and T.P. Ahern. 1976. Effect of petroleum hydrocarbons on algal physiology: review and progress report. In: A.P.M. Lockwood, ed. Effects of Pollutants on Aquatic Organisms London, Cambridge University Press, p 107-125.

Vandermeulen, J.H., B.F.N. Long and L.D'Ozouville. 1981. Geomorphological alteration of a heavily oiled saltmarsh (O/E Grand, France) as a result of massive clean up. In: Proceedings of the 1981 Oil Spill Conference, March 2-5, 1981, Atlantic , GA. EPA/AP1/USCG:519-524.

Vandermeulen, J.H. and D.J. Scarratt. 1979. Impact of oil spills on living natural resources and resource-based industry. In D.J. Scarratt, ed. Evaluation of recent data relative to potential oil spills in the Passamaquoddy Area. Canada Fish. & Mar. Serv. Tech. Rept. No. 901. p. 91-96.

Ward, C.H., M.E. Bender and D.J. Reish (Eds.). 1980. The offshore ecology investigation: Effects of oil drilling and production in a coastal environment. Rice University Studies: Vol. 65, Nos. 4 & 5.

Wright, D.G. 1982. A discussion paper on the effects of explosives on fish and marine mammals in waters of the Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. No. 1052. 16 p.

## II. ENVIRONMENTAL HAZARDS POSED TO SEABIRDS BY EAST COAST OFFSHORE OIL EXPLORATION

Bourne, W.R.P. 1976. Seabirds and pollution In. R. Johnston (ed.) Marine Pollution, London, Academic Press, p. 403-502.

Bourne, W.R.P., J.D. Parrack & G.R. Potts. 1967. Birds killed in the Torrey Canyon disaster. Nature 215:1123-1125.

Brown, R.G.B. 1980. Marine birds. In: Offshore Environment in the 80's. Proceedings of a Workshop on Environmental Considerations of East Coast Offshore Hydrocarbon Development, St. John's, Nfld.

Brown, R.G.B., D.N. Nettleship, P. Germain, C.E. Tull & T. Davis. 1975. Atlas of Eastern Canadian Seabirds, Ottawa: Canadian Wildlife Service.

Brown, R.G.B., D.I. Gillespie, A.R. Lock, P.A. Pearce & G.H. Watson. 1970. Bird mortality from oil slicks off eastern Canada, February-April 1970. Can. Field-Nat. 87 (3): 225-234.

Clark, R.B. 1968. Oil pollution and conservation of seabirds In: Proceedings of International Conference on Oil Pollution of the Sea. Rome. Report of the proceedings. p. 76-112.

Davies, J.M., R. Hardy & A.D. McIntyre. 1981. Environmental effects of North Sea oil operations. Mar. Pollut. Bull. 12:412-416.

Holmes, W.N. & J. Cronshaw. 1977. Biological effects of petroleum on marine birds. In: D.C. Malins (ed.) Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms; Vol. 2, Biological Effects. New York, Academic Press. p. 359-398.

Hope Jones, P. 1980. The effect on birds of a North Sea gas flare. Br. Birds 73(12):547-555.

Hope Jones, P. J.-Y. Monnat, C.J. Cadbury & T.J.S. Stowe. 1979. Birds oiled during the Amoco Cadiz incident: an interim report. Mar. Pollut. Bull. 9(11):307-310.

Miller, D.S., D.B. Peakall & W.B. Kinter. 1978. Ingestion of crude oil: sublethal effects in Herring Gull chicks. Science 199: 315-317.

Owens, E.H. & G.A. Robillard. 1981. Shoreline sensitivity and oil spills - a re-evaluation for the 1980's. Mar. Pollut. Bull 12(3): 75-78.

Peakall., D.B., D. Hallett, D.S. Miller, R.G. Butler & W.B. Kinter. 1980. Sub-lethal effects of ingested crude oil on Black Guillemots: a combined field and laboratory study. Ambio 9(1): 28-30.

Sprague, J.B., J.H. Vandermeulen & P.G. Wells. 1981. Oil and dispersants in Canadian seas - recommendations from a research appraisal. Mar. Pollut. Bull. 12(2):45-46.

Vermeer. R. & K. Vermeer. 1974. Oil Pollution of Birds; an abstracted bibliography. Can. Wildl. Serv. Pesticide Section, MS. Report No. 29.

## III. COUNTERMEASURES - RESPONSE, EQUIPMENT AND TECHNIQUES

Clark, R.C. Jr. and D.W. Brown. 1977. Petroleum: Properties and Analyses in Biotic and Abiotic Systems. In (Malins, D.C., ed.) Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Vol. 1. Nature and Fate of Petroleum. New York, Academic Press p. 1-89.

Dahl, E., T-I. Bern, M. Golden, G. Engen, 1983. Risk of Oil and Gas Blowout on the Norwegian Continental Shelf. Offshore Technology Testing and Research Group. STF88A82062.

Dillon,( M.M.) Ltd. 1982. Survey of Countermeasures Systems for Hazardous Materials Spills. Prepared for the Environmental Emergencies Branch, Environmental Protection Service

Environment Canada, 1973. Guidelines on the Use and Acceptability of Oil Spill Dispersants. EPS-1-EE-73-1.

Fingas, M.F. et al., 1978. (The Basics of Oil Spill Cleanup; with particular reference to Southern Canada.) Environmental Emergencies Branch. Ottawa.

Hildebrand, L.P., 1980. An Assessment of Chronic Oil Pollution in Atlantic Canada. Environmental Protection Service, Economic and Technical Review Report. EPS-3-AR-81-2.

Interra Environmental Consultants Ltd., 1983. State-of-the-Art Survey of Oil-Spill Detection, Tracking and Remote Sensing in Cold Climates. Prepared for Environment Canada.

National Academy of Sciences, Washington. 1975. Petroleum in the Marine Environment. Workshop on Inputs, Fates and the Effects of Petroleum in the Marine Environment, May 1973. Airlie, Virginia.

National Research Council, 1981. Safety and Offshore Oil, Committee on Assessment of Safety of OCS Activities, Marine Board, Assembly of Engineering, NRC, Washington, D.C.

Ross, S.L., 1980. Oil Spill Countermeasures in Offshore Production. Arctic Environmental Workshop, Fairmont Hot Springs, B.C.

Ross, S.L., 1982. Potential Large Oil Spills Offshore Canada and Possible Response Strategies. Discussion paper prepared for the Environmental Protection Service.

Thornton, D.E. and H. Hume, 1982. Countermeasures for Major Oil Spills Offshore Canada. Spill Technology Newsletter, 7 (4): 90-92.

Vandermeulen, J., 1982. Oil Spills: What Have We Learned? In: Sprague, J.B. et al.(eds) Oil and Dispersants in Canadian Seas - Research Appraisal and Recommendations. Environment Canada, Economic and Technical Review Report. EPS-3-EC-82-2. p. 29-46.

National Academy of Sciences, Washington. 1975. Petroleum in the Marine Environment - Workshop on Inputs, Fates and the Effects of Petroleum in the Marine Environment, May 1973. Airlie, Virginia.

National Research Council, 1981. Safety and Offshore Oil. Committee on Assessment of Safety of OCS Activities, Marine Board, Assembly of Engineering, NRC, Washington, D.C.

Ross, S.L., 1980. Oil Spill Countermeasures in Offshore Production. Arctic Environmental Monitoring Programs Hot Springs, B.C.

Ross, S.L., 1982. Potential Large Oil Spills Offshore Canada and Possible Response Strategies. Discussion paper prepared for the Environmental Protection Service.

Thornton, D.E. and H. Ross, 1982. Countermeasures for Major Oil Spills Offshore Canada. Spill Technology Newsletter, 7 (3): 90-92.

Vandermeulen, J., 1982. Oil Spills: What Have We Learned? In: Sprague, J.B. et al (eds). Oil and Dispersants in Canadian Seas - Research Appraisal and Recommendations. Environment Canada, Economic and Technical Review Report: EPS-3-EC-82-2, p. 31-45.